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The Design and Application of Flameproof Lighting Equipment

By D. A. STRACHAN *(Fellow)*

Summary

In industries where there are explosive or inflammable hazards, it is required that the lighting system should preclude the possibility of explosion or fire as a result of accidental sparking or damage to the equipment.

Explosion hazards may be divided into two main groups:—

(i) Hazards in buildings or parts thereof where gases, vapours or volatile liquids are present and may form an explosive mixture with air, either at room temperature or at some higher temperature;

(ii) Hazards where dusts may be in an explosive mixture with air.

In general, one of two systems of lighting may be employed where an explosive or inflammable hazard exists:—

(i) By an external lighting system whereby the light sources are placed outside the building and arranged to project light through "windows";

(ii) By an internal lighting system:—

(a) In which flameproof lighting equipment must be employed throughout owing to the nature and extent of the hazard, or

(b) In which flameproof equipment is required only for specific areas where a "local" hazard may exist, e.g., in paint spraying booths.

This paper relates solely to flameproof lighting equipment for use in hazardous situations, and does not include reference to external lighting systems or to the installation of heavy-duty dustproof fittings which may be acceptable for some locations where certain dusts may be in an explosive mixture with air. Furthermore, the paper is concerned primarily with features of mechanical design, although reference is made to the factors which influence the lighting result.

(1) Introduction

The use of flameproof electric lighting equipment has developed considerably during the past 20 years, largely as a result of the use of highly volatile and inflammable solvents in various manufacturing processes. In addition, there has been a continued demand for such equipment in the mining, gas and petroleum industries.

Safety apparatus can be conveniently classified in two main groups: (a) The major group comprising flameproof equipment, and (b) A smaller group which comprises intrinsically or inherently safe circuits and/or apparatus.

Flameproof enclosures of any type must be so designed that they will withstand, without fracture, a severe internal explosion, and at the same time prevent the flame generated by such an internal explosion from igniting the surrounding atmosphere.

In the early days of flameproof enclosures the main effort was directed towards relieving the internal pressure set up by an explosion within the housing itself. Many of the devices used took the form of simple safety valves, such as spring-loaded bolts; the aim was to lessen the risk of damage to the enclosure by limiting the internal pressure, allowing at the same time a lighter form of construction.

However, this earlier type of construction was soon abandoned and the present practice of designing an enclosure, having specified minimum flange and joint clearances, was adopted. The enclosure is made sufficiently strong to withstand a severe internal explosion.

It has been generally accepted that the protection afforded by a flange gap results

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from the cooling during its passage through the flange of the flame generated by an internal explosion. More recent research work[1]), however, has shown that turbulence and lag on ignition have some controlling influence on the process of ignition by the flame and hot gases projected through the gap of a flanged enclosure; research on the problem is continuing.

For intrinsically safe apparatus, the conditions are entirely different. Whilst the flameproof enclosure admits the possibility of, and makes allowance for, an internal explosion, the term "intrinsically safe" [2]) denotes that the apparatus is so constructed that when connected and used under the prescribed conditions any sparking that may occur in normal working is incapable of causing an explosion of the prescribed inflammable gas or vapour. However, intrinsic safety can be attained only in apparatus and circuits in which the current is small—such as bells, telephone and signalling systems. The principle of "intrinsic safety" is not normally applied to lighting apparatus or circuits except where low-wattage handlamps are supplied from low-voltage transformers having special protection against short-circuit faults. Even so, it is the circuit and not the lamp which is intrinsically safe, since the incandescent filament would be a source of danger if the fitting and lamp were broken.

For these reasons the alternative of providing flameproof equipment must be adopted.

(1.1) Means by which Inflammable Gases and Vapours can be Ignited[3])

Inflammable gases and vapours may be ignited by means which can be classified under six general headings, namely :—

(i) By Flame : Any flame, unless it is of extremely short duration, will ignite an inflammable gas or vapour when mixed with air in explosive concentration. Nevertheless, as the ignition characteristics of different inflammable gases or vapours vary, it is possible that a flame which will ignite one may not ignite another. Evidence of such a difference is confirmed by the different dimensions of the "safe" gaps permitted for various gases and vapours (see Table 1).

(ii) By Electric Arc : The charactertistics of an arc (here interpreted to mean arcing on circuits where the applied voltage is sufficiently high to maintain the arc) are the emission of heat and light. The heat generated at the point(s) of arcing is normally sufficiently high to ignite an explosive gas-air mixture if the arcing is maintained; it has not been confirmed whether temperature alone is the deciding factor, since considerable free electrification exists.

(iii) By Electric Sparks : The ability of an electric spark to cause ignition is more dependent upon the voltage of self-induction than upon the operating voltage. Very little energy suffices to ignite an inflammable mixture provided that it is released in the spark, but the amount of energy which must be available in the circuit to produce an incendive spark varies considerably with the distribution of the energy in the circuit at the instant when the spark is produced. The limitation of the energy that might be liberated in the spark when a circuit is broken is the basis of intrinsic safety.

(iv) By Hot Wires (e.g., lamp filaments) : Research and tests[4]) have shown that when a heated tungsten wire is exposed in the presence of a methane-air mixture, its temperature increases due to oxidation, and the resulting flame, though of short duration, can easily cause ignition.

(v) By Hot Surfaces : The rate at which an explosive mixture may react when brought into the presence of a hot surface depends upon the temperature of the surface. The reaction is by no means spontaneous and there is a time lag, depending upon the temperature of the surface, before ignition

may occur. For various conditions there are certain temperature limits below which ignition is not possible.

(vi) Frictional Sparks: This refers to sparks caused by small particles of mineral or metal which have been heated to incandescence by friction. Should the material be oxidisable the particles may burn in air, and where this occurs there is flame in addition to a heated solid surface acting as a potential igniting medium. An ignition is less likely to occur when the hot particles do not burn in air.

A form of abrasive sparking capable of igniting an explosive gas-air mixture under certain circumstances, results when a cast-iron body coated with aluminium paint is struck by a metal object so that sparks are produced.

In general it should be emphasised that whilst there is no essential difference between the behaviour of various gases and vapours in explosive mixture with air relative to the different means of ignition quoted, there are, nevertheless, wide variations in the reaction between different gases and vapours when ignited by any one method.

(2) Classification of the Hazard

(2.1) Gases and Vapours

The inflammable gases and vapours met with in industry are grouped or classified according to the permissible gap dimensions of the flameproof enclosure, related to the particular hazard.

At the present time information on "gap dimensions" is available for 32 different gases and vapours. Initially, the experimental work related solely to methane (firedamp), but subsequently the classification was extended to include inflammable gases and vapours present in industries other than mining. Much of the more recent experimental work has been carried out on behalf of the Testing Authority by the Safety in Mines Research Establishment in conjunction with the British Electrical and Allied Industries Research Association.

Before it was possible to group the various inflammable gases and vapours it was necessary to determine the most incendive internal mixture and the most easily ignited external mixture in terms of the volumetric quantity of gas or vapour in the mixture with air. With this information available it was then practicable first to determine the individual safe gaps relative to the critical concentrations of the gas or vapour, and then to group the gases and vapours relative to the safe gap dimension.

On this basis the inflammable gases and vapours have been divided into four main groups, and Table 1 (extracted from B.S.229: 1946) shows the grouping at present adopted together with the corresponding maximum permissible gap dimensions. Only the Class "A" figures are quoted since they relate to normally air-filled apparatus, which includes lighting equipment.

Some explanatory notes[5] on the grouping may be appropriate.

Methane, the major constituent of firedamp which is found in coalmines, is listed alone in Group I.

The Group II inflammable gases and vapours are sub-divided into four sections. Blast-furnace gas, sub-class (a), is of varying composition, the major inflammable constituent being carbon monoxide (about 33 per cent.), with nitrogen (about 56 per cent.) as an inert diluent. Sub-class (b) consists of a group of hydrocarbons which, being the products of the distillation of crude oil, mainly concern the petroleum industry and the users of petroleum. Sub-class (c) includes liquids derived from coal tar, whilst sub-class (d) lists various solvents found in different industrial processes, e.g., the cellulose solvents used in the manufacture of paints and varnishes.

Group III includes coal gas (town's gas) and coke oven gas; these are of varying composition.

Under Group IV are five gases which are referred to as "Excluded Gases and

Table 1.

Grouping of Inflammable Gases and Vapours with corresponding Gap Dimensions.

Group	Inflammable Gas or Vapour	Max. Permissible Gap
		in.
I	Methane (firedamp)	0.020
II a	Blast Furnace Gas	0.016
	Carbon Monoxide	,,
b	Propane	0.016
	Butane	,,
	Pentane	,,
	Hexane	,,
	Heptane	,,
	Iso-Octane	,,
	Decane	,,
c	Benzene	0.016
	Xylene	,,
	Cyclo-Hexane	,,
	Ammonia	,,
d	Acetone	0.016
	Ethylene	,,
	Methyl-Ethyl-Ketone	,,
	Methyl Acetate	,,
	Ethyl Acetate	,,
	Propyl Acetate	,,
	Butyl Acetate	,,
	Amyl Acetate	,,
	Methyl Alcohol	,,
	Ethyl Alcohol	,,
	Iso-Butyl Alcohol	,,
	Butyl Alcohol (normal)	,,
	Amyl Alcohol	,,
	Ethyl Ether	,,
	Ethyl Nitrite	,,
III	Coal Gas (Town's Gas)	0.008
	Coke-oven Gas	,,
	Ethylene Oxide	,,
IV	Excluded Gases and Vapours	
	Acetylene	
	Carbon Disulphide	
	Hydrogen	
	Water Gas	
	Ethyl Nitrate	

Vapours." The maximum safe gap for these gases, as determined experimentally, is too small to be practicable or to justify flameproof certification on the basis of type tests.

(2.2.1) *Flash Points of Inflammable Substances*

The combustibles which are scheduled in Table 1 include liquids that differ in volatility over a wide range. The "flash point" of a liquid is defined as "an arbitrary ignition temperature of its saturated vapour and may be regarded as a rough index of the liability of the liquid to form explosive mixtures with air and, therefore, as a measure of the risk of explosion where they are used in industrial processes."

The tendency of a liquid to evaporate increases with the temperature rise, and a relatively small increase in an ambient temperature may well transform a normally "safe" liquid into one which is potentially dangerous. The "flash point" is, therefore, an important factor which should be taken into account when assessing the hazard. A schedule which lists the "flash points" of some inflammable substances is quoted in Appendix "E" of BS.229 : 1946.

It is known that for most gases and vapours there is a maximum and minimum concentration of the inflammable gas or vapour in air above or below which combustion is not sustained. These are referred to as the "limits of inflammability," which can be quoted as the range of mixtures of the combustibles with air within which a self-propagating explosion can be produced. Appendix "D" of B.S.229: 1946 tabulates some data originating from the systematic research which has been carried out on spaced metal flanges as applied to flameproof enclosures.

2.3) The Dust Hazard

Certain industrial dusts in the atmosphere may be potentially as dangerous as an inflammable gas or vapour in an explosive mixture with air.

The late Dr. R. V. Wheeler conducted a series of experiments on various dusts, and in his report(6) on "Explosions of Carbonaceous Dust" divided them into three classes. These were as follows:—

Class 1.—Dusts which ignite and propagate flame readily, the source of heat required being comparatively small, e.g., an electric spark or an exposed incandescent filament.

Class 2.—Dusts which are readily ignited but which, for the propagation of flame, require a source of heat (a) of large size and high temperature such as an electric arc, or (b) of long duration.

Class 3.—Dusts which do not appear to be capable of propagating flame under any conditions likely to occur in a factory, (a) because they do not readily form a cloud in air, (b) because they are contaminated with a large quantity of incombustible material, or (c) because the materials of which they are composed do not burn sufficiently rapidly to produce enough gas.

For the sake of convenience, only the dusts of Class 1 are given in Table 2. In this connection, however, it should be mentioned that the current Factory Department Memorandum on the "Inflammability of Dusts" lists approximately 150 dusts in Class 1 compared with the 60 odd referred to by Dr. Wheeler.

It is necessary, finally, to emphasise the main difference between a gas or vapour explosion and one resulting from dust. In gas and vapour explosions the severity is dependent upon the supply of oxygen at the point of ignition; in dust explosions each particle is supplied with its surrounding envelope of oxygen, so that the propagation wave is only limited by the quantity of airborne dust or the space within which the explosion occurs.

Table 2.

Classification of Dusts.
By Dr. R. V. Wheeler.

CLASS I

Aceroides or Yacca gum	Hops (spent) (dust room sample)
Aluminium powder (impure)	Keronikon (roasted horns and hoofs)
Bitumen (Iraq)	Keronyx (casein and formaldehyde)
Briquette	Liquorice root
Cascara sagrada	Locust bean kernel
Cellulose acetate	Locust meal
Cellulose acetate (granular)	Maize
Cellulose acetate powder mixed with 40 per cent. inert matter	Malt
	Milk powder
Chicory	Mimosa bark
Cocoa	Oat dust
Compound cake	Oat husk
Congo copal	Pitch dust
Cork	Raschig (synthetic resin and wood)
Cornflour	Rape seed
Cotton (ground)	Rice bran (parboiled)
Dextrine (calcined farina)	Rice bran (Rangoon)
Distillery meal	Rice meal and sugar refuse
Ebonite	Rosin (natural)
Erinoid	Rosin (nitrated)
Ferro-manganese (80 per cent. iron and 20 per cent. manganese)	Salicylic acid (re-sublimed)
	Shellac
Flour (flour mill)	Soya bean (extracted)
Gentian root balloon dust	Soya bean (unextracted)
Grain (flour mill)	Spice rooms (cattle food)
Grain (grain storage)	Starch
Gramophone record	Sugar
Gum (No. 1 British) (calcined maize starch)	Sugar pulp
Gum (No. 2 Core) (calcined starch refuse)	Sunflower seed cake
Gum gatto (fine)	Syrolit
Gum (synthetic resin, natural rosin, acetanilid, beeswax)	Tea
	Wood flour

(3) The Principles of Flameproof Enclosure

(3.1) The Need for Flameproof Equipment

The problems of design, manufacture and use of electrical apparatus in situations where there is danger of fire or explosion demand a great deal of attention, particularly with the increasing use of highly inflammable liquids and gases. A "hazardous situation" could be defined shortly as premises, works, stores or other locations where inflammable gases or volatile liquids are used, stored or manufactured, and where the possibility exists of such explosive mixtures coming into contact with an igniting medium. It would also apply to situations where combustible dusts are present in the air in such proportion and constitution as to present an explosive hazard.

The safe operation of electric lighting in such locations demands that special pre-

cautions be taken. These mainly concern the construction and installation of the fittings and ancillary apparatus.

(3.2) The Fundamentals of Flameproof Construction

A flameproof enclosure is defined in B.S.229: 1946 as follows: "A flameproof enclosure for electrical apparatus is one that will withstand, without injury, any explosion of the prescribed inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus (and recognised overloads, if any, associated therewith), and will prevent the transmission of flame such as will ignite the prescribed inflammable gas which may be present in the surrounding atmosphere."

Owing to changes in internal temperature, lighting fittings "breathe," making it very difficult to prevent gases of the atmosphere external to the fitting from entering the fitting. Consequently, the possibility of an explosive mixture being drawn into the housing has to be accepted. Flameproof construction demands that if an internal ignition occurs, the enclosure itself will be sufficiently robust to withstand the explosion without damage, and that the flame when passing through to the outside atmosphere will be incapable of igniting the surrounding gas/air mixture. [See (1).]

To satisfy these demands requires enclosures having both a minimum breadth of flange and a maximum permissible width of gap between machined surfaces. As applied to lighting fittings, B.S.229: 1946 specifies that the length of the flame path through or across any joint surface or opening in the flameproof structure shall be not less than $\frac{1}{2}$ in. for Group I, IIa or IIb gases and vapours; for other inflammable gases and vapours scheduled in Table 1, the breadth of all joints must be not less than either $\frac{1}{4}$ in. or 1 in. depending upon the internal volume of the casing. The maximum permissible width of gap between flanges varies from 0.020 in. to 0.008 in. according to the inflammable gas or vapour involved (see Table 1).

It will be noted that the words "prescribed inflammable gas" are emphasised in the definition of a flameproof enclosure given earlier. This stresses the importance of any fitting being tested and certified in the appropriate or similar gas to that in which it is to be used; a fitting tested for, say, Group I only should not be installed where gases or vapours of other groups are present. The reduction in the permissible gap dimensions for Group II and III gases/vapours is related mainly to the increased speed of the flame traverse of these different gases which in turn involves the effects of turbulence and lag on ignition.

The specification of gap and flange dimensions thus constitutes the basic protection of a flameproof enclosure.

The earlier principle of cooling only was first employed in the researches of Sir Humphrey Davy on the comparative inflammability of fuels, on the heat emitted by combustion and on the passage of flame along tubes containing inflammable mixtures; these researches led to the development of the miners' flame safety lamp. The flame of a miners' safety lamp is fully capable of igniting an explosive mixture, but the combustion is limited to the relatively small interior of the lamp by the cooling effect of the gauze screen(7).

(3.3) Factors Affecting the Design of Flameproof Lighting Equipment

Flameproof lighting fittings of all types must comply with the same requirements in regard to the breadth of flanges and the width of gap as any other flameproof apparatus. This factor in itself limits the construction to one which will satisfy the requirements of a flameproof enclosure, and therefore the basic design of any fitting is fairly closely defined within the framework of the appropriate specifications. This may also have some bearing on the "lighting efficiency" of the fitting since it is possible that the preferred light distribution could be influenced, to some extent, by the "flameproof" requirements. It is fair to say, however, that a fairly wide range of

flameproof lighting fittings have been developed, although there is ample scope for new designs.

The basic mechanical features of any flameproof lighting fitting are clearly specified. B.S.229 : 1946 requires all joints in a flameproof enclosure between compartments or components, or between covers and compartments to be either flanged (Fig. 1a and b),* spigotted (Fig. 1c) or screwed without the intervention of any loose or perishable packing. Furthermore, the terminal chamber must be a separate flameproof entity, walled off from the main chamber by a solid flameproof partition, provision being made for sealing the incoming cables where necessary. The holes for bolts or set-screws used for the attachment of covers and other components must not pass through the wall of the enclosure, but must be either in external flanges or "bottomed." In the latter construction, there must be a certain minimum thickness of metal between the bottom of the hole and the outside edge of the flange (Fig. 1b). The heads of bolts or nuts used for securing removable covers must be adequately shrouded against unauthorised interference (Fig. 2). Where studs are screwed through the wall of an enclosure, they must be riveted over or welded on the inside to prevent removal (Fig. 3).

In addition to B.S.229 : 1946, the designs of this type of equipment must take into account the requirements of one other specification, namely, B.S.889 : 1947, which specifically refers to Flameproof Electric Lighting Fittings.

Although the scope of this specification covers fixed lighting fittings of the well-glass and bulkhead types, it is regarded in the absence of further specifications covering other designs as being applicable to all flameproof lighting fittings, except portable hand lamps; particularly is this so with regard to the test requirements detailed in Section (4.2) of this paper.

The major portion of B.S.889 deals with what may be regarded as the most vulnerable part of the fitting, namely, the glass cover, and is very largely a specification for the glass manufacturer. Six preferred sizes of well-glass are listed, although other

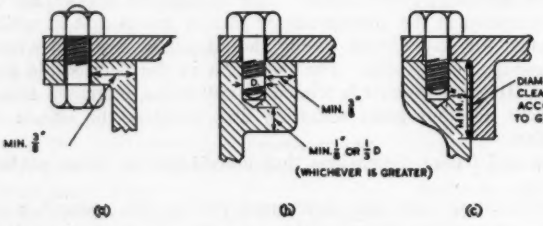


Fig. 1. Examples of flange and spigot joints: (a) external flange, (b) internal flange, (c) spigot.

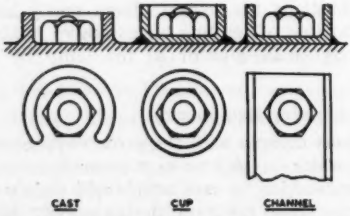


Fig. 2. Three methods of shrouding bolt heads or nuts in flameproof enclosures.

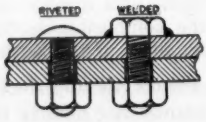


Fig. 3. Alternative methods of securing studs in flameproof enclosures.

* Figs. 1-6 are intended to illustrate basic principles and do not purport to indicate actual constructional details.

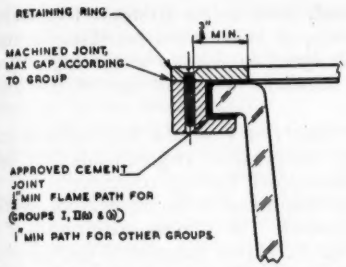

RETAINING RING
MACHINED JOINT, MAX GAP ACCORDING TO GROUP
APPROVED CEMENT JOINT
MIN FLAME PATH FOR GROUPS I, II & III
MIN PATH FOR OTHER GROUPS

Fig. 4. Typical arrangement for mounting glass in the retaining ring.

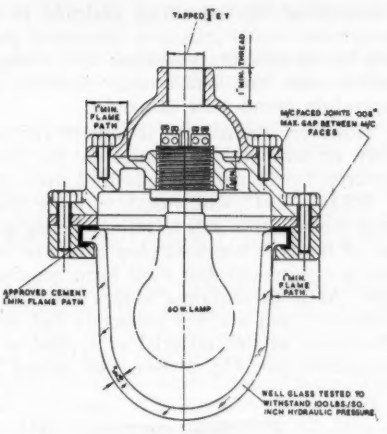


Fig. 5. Typical well-glass fitting (for Groups II and III conditions) illustrating the basic principles of flameproof design.

sizes are not precluded, but no such standardisation is attempted for the bulkhead glasses. One amendment to the Standard since its date of publication relates to the acceptability of an annealed glass (styled type "B") in place of the more usual toughened glass (styled type "A") for flameproof lighting fittings. This change was made to allow the use in flameproof lighting fittings of prismatic or diffusing glass, which is not normally supplied in toughened form.

Fittings employing type "B" glass, which are not required to comply with the specified Impact Tests, are likely to be suitable where less strenuous service conditions exist, but the type "A" glass is always to to be recommended when the equipment may be subject to mechanical damage.

Although not strictly a factor affecting the design of such lighting fittings, it is worthy of mention that type "A" and "B" glasses are required to have a light absorption not exceeding 15 per cent. per inch.

Wherever a glass comprises part of the flameproof enclosure, as in a lighting fitting, the glass must be embedded in an approved-type cement as detailed in B.S.229 : 1946, and held in position by a substantial metal backing ring (Fig. 4). The basic principles involved in the design of a flameproof well-glass fitting for use where Group II or Group III conditions apply are shown in Fig. 5.

A most important feature of flameproof lighting fittings design relates to the temperature requirements; B.S.889 requires that the temperature rise of any part of the external surface of a fitting shall not exceed 50 deg. C., with an ambient temperature between 15 and 35 deg. C.

In recent years there has been some controversy with regard to this particular requirement. It has been suggested that whilst the specified maximum temperature is reasonable for certain applications—e.g., where cellulose solvents are present—it is a restrictive factor in the design of lighting fittings for use where other Group I or II conditions exist, since compliance with the temperature test requirement necessitates a construction which is of sufficiently large volume to allow efficient cooling. Supporters of this viewpoint therefore claim that there is no differentiation between hazards, and that advantage cannot be taken of the fact that smaller fittings operating at a slightly higher temperature than that specified would be suitable for many of the applications.

One argument against such a proposal is that the acceptance of another class

of flameproof lighting fitting designed to comply with a less stringent temperature requirement, would introduce associated problems of installation; for instance, there could be no absolute guarantee that fittings designed to operate at the higher temperature were not inadvertently installed in situations where fittings of the lower temperature group were demanded.

However, whilst there is support for both points of view, the fact remains that, rightly or wrongly, no change in the present temperature requirements has been sponsored by any of the industrial users of flameproof lighting equipment.

B.S.889 : 1947, which deals with the standard requirements for flameproof lighting fittings is applicable only to fittings having glass covers. The ultimate certification of fittings of the type which employ covers of the acrylic plastic polymethyl methacrylate, either in cast, moulded or sheet form, requires the preparation of an appropriate specification. At the present time, fittings which make use of this material may only be granted "approval" and are not subject to full certification. Much valuable data[8] on the performance of this material as applied to fluorescent lighting fittings of flameproof construction (see Fig. 6) has been gained from laboratory researches and from the

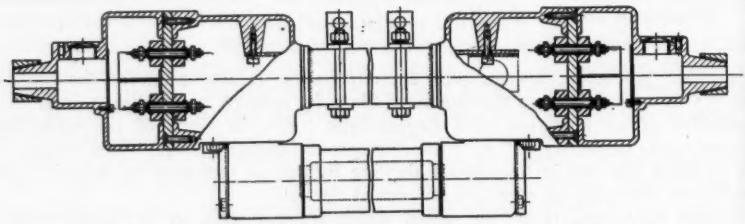


Fig. 6. Example of flameproof fluorescent fitting (Group I). Note terminal arrangements at cable entry positions.

experimental coal-face lighting installations sponsored by the National Coal Board and a draft Standard is now being prepared. The acceptance of this specification for Group I fittings will no doubt be a factor which will influence future designs.

It is perhaps appropriate to list one other factor which may have some bearing on the design and/or construction of certain types of flameproof fitting, particularly those for use in coal mines. Recently, attention has been focused on the abrasive or frictional sparking which may result when certain aluminium alloys are subjected to a glancing blow by some other metal object; this relates to the magnesium content of the alloy and the matter is now the subject of active research. It should also be mentioned that, under certain conditions, similar abrasive or frictional sparking capable of igniting firedamp can result from fittings constructed in cast-iron which are coated with aluminium paint[3]; it is therefore suggested that the use of aluminium paint should be avoided for such flameproof lighting fittings.

Finally, subsequent to certification, new fittings of flameproof construction must be tested at the prototype stage for the particular group by the Testing Authority, in accordance with the requirements of the appropriate specifications.

(4) The Testing and Certification of Flameproof Lighting Equipment

(4.1) The Testing Station[9]

This paper would not be complete without a brief reference to the Ministry of Fuel and Power's Research Establishment at Buxton, which is the recognised Testing Authority in Great Britain for flameproof electrical apparatus. The term "Buxton

certified" has come to be acknowledged internationally as being a guarantee of any flameproof apparatus.

Historically it is worthy of note that the first independent certificate of flameproof enclosure in Britain was issued by the Mining Department of Sheffield University during August, 1922.

Initially, the development of a routine test for flameproof apparatus was related to equipment which was to meet the requirements of the coal mining industry, and it was not until 1928 that a number of flameproof units were tested with pentane-air mixtures in addition to the methane-air mixtures which were used for the earlier tests. Within two years experiments were being conducted to include 10 industrial gases and vapours; these experiments subsequently provided valuable data[10] relating to the scope of the routine tests.

With the establishment of the Buxton Testing Station in 1931, the Mines Department of the Board of Trade took over responsibility for the testing work. Further research on the characteristics of industrial gases and vapours was undertaken, and the routine testing of commercial flameproof enclosures of all types continued.

More recently the Testing Station has come within the organisation of the Ministry of Fuel and Power, but its function remains the same. A full review of the work of the Testing Station year by year is to be found in the Annual Reports of the Ministry of Fuel and Power Safety in Mines Research Establishment.

(4.2) Tests Applicable to Flameproof Lighting Fittings

The test requirements may be grouped under three general headings, namely:—

(a) Mechanical tests,
(b) Tests of flameproofness,
(c) Temperature tests.

The mechanical and temperature tests are normally undertaken at the manufacturers' works, or elsewhere on behalf of the manufacturers; the former include type and individual tests which may or may not be required by the Testing Authority as a condition of certification, whilst the latter relates to the operating temperature of the complete fitting. The essential tests to prove the "flameproofness" of the fitting are performed at the Ministry of Fuel and Power Testing Station.

(4.2.1) *Mechanical Tests*

B.S.229: 1946 specifies the particular test requirements. A pressure test, applied either hydraulically or pneumatically, may be required as a type test to prove the strength of the enclosure. Where this is so the Testing Authority will normally inform the manufacturer after the explosion tests have been carried out. The pressure test specified requires that a specimen fitting must withstand an internal pressure of not less than one and a half times the maximum pressure developed while it was undergoing the flameproof test with inflammable gas, or of 50 lb. per sq. in. above atmospheric pressure, whichever is the greater.

An individual pressure test, generally similar to the type test above, which would be applicable to each and every fitting, may also be demanded at the discretion of the Testing Authority.

Further individual tests, from which no exceptions are permitted, relate to the testing of all flanged joint surfaces to check for deviations from the true plane surface, and also tests of the gaps between such surfaces after the fitting has been assembled.

In addition to the foregoing, the particular tests applicable to well-glasses and bulkhead-type glasses as used in flameproof lighting fittings are detailed in B.S.889 : 1947. These include a static hydraulic pressure test which must be applied to each well-glass and bulkhead glass, and two type tests—an impact test (for type "A" glasses only) and a thermal shock test. The former type test demands

that the glass shall withstand an impact of a certain specified weight and ballistic swing without fracture, whilst the latter type test imposes a thermal shock between varying temperature limits which the glass must resist without showing signs of fracture. All these tests are to be carried out on unmounted glasses. It must be emphasised that the individual static hydraulic test does not apply to the fitting as a whole, which can be manufactured as a part of a type, provided that the type has been submitted for flameproof testing.

The tests on the glasses may not directly concern the fittings manufacturer since it is often the responsibility of the glass suppliers to guarantee compliance with the specifications.

(4.2.2.) *Tests of Flameproofness*

The conditions of test are described in BS.229: 1946 and the Ministry of Fuel and Power Testing Memorandum No. 4—"Test and Certification of the Flameproof Enclosure of Electrical Apparatus."

For the purpose of the test the fitting is filled with, and surrounded by, the appropriate gas mixed with air in those proportions that will provide (a) the most explosive mixture within the fitting, and (b) that mixture surrounding the enclosure which is most readily ignited by flame. The internal explosive mixture is then ignited under controlled conditions by a secondary discharge from an induction coil or by the rupture of a fusible link.

Table 3 lists the gases and vapours which are used for the flameproof tests, according to the group(s) for which the fitting is designed.

A fitting is considered to have failed a test if:—

(i) The structure suffers injury,
(ii) The surrounding inflammable gas/air mixture is ignited,
(iii) An inadequate factor of safety is demonstrated.

Table 3.
Gases used for the Flameproof Tests.

Group	Air-filled Apparatus	
	Internal Gas	External Gas
I	Methane*	Methane
II	Pentane	Pentane
III	Substitute Gas†	Substitute Gas

* Natural gas, containing about 90.6 per cent. CH_4 and 4.0 per cent. C_2H_6, is used to represent firedamp.
† A substitute gas, consisting of a mixture of hydrogen and methane in the proportion of 85/15 is used to represent the variable product Coal gas or Town's gas.

(4.2.3) *Temperature Test*

It is a requirement of BS.889: 1947 that the temperature-rise at any part of the external surface of the fitting shall not exceed 50 deg. C. when the ambient temperature is between 15 deg. C. and 35 deg. C. A type test on a specimen fitting is therefore demanded in order to check compliance with the specification.

The apparatus for thermal testing and the study of convection streams in lighting fittings is already well known ([11]) and need not be referred to here.

In making the temperature test due regard must be taken of the rating of the lamp (or lamps) for which the fitting is designed, and also its normal mounting position in service. The test requirements presuppose the use of metal filament lamps and it would be an advantage if the upper limit of the permissible variation in wattage could be similarly defined for fittings employing discharge lamps, since

the operating characteristics of these lamps are determined by their associated control gear.

The test requires that the measurements to determine the maximum hot-spot temperature, which may be on the glass or body of the fitting, should be made with the fitting operating in its normal mounting position, whether this be vertical, horizontal or inclined. Whilst this is perfectly reasonable for fittings intended for use in fixed positions, it is suggested that for those fittings where the particular application may warrant their use in positions other than the normal, the hot-spot temperature should be determined for more than one mounting position.

(4·3) Additional Requirements

Subject to the issue of a flameproof certificate by the Ministry of Fuel and Power, each fitting must be permanently marked with certain essential data (see Clause 18, B.S.889 : 1947); the registered flameproof mark, comprising the well-known letters "FLP" outlined by a crown, may be reproduced on the equipment if the manufacturer holds a licence to apply this mark. These details are helpful in identifying the particular equipment to the user.

Subsequently, the details of any changes made in the design of any fitting already certified must be submitted to the certifying authority for approval and record purposes.

Finally, it is essential that certified flameproof fittings should be maintained in good and proper condition during service.

(5) Installation and Maintenance of Flameproof Lighting Equipment

It will be recognised that special care must be given to the installation and maintenance of flameproof lighting equipment, since insufficient attention to these factors may well result in a safe piece of equipment being converted into one which is potentially dangerous.

With regard to installation, the types of wiring recommended for danger areas are (a) armoured cable (for Group I, II and III conditions), (b) solid drawn conduit (for Group II and III conditions) and (c) mineral-insulated copper sheathed cable (for Group II and III conditions). In selecting a particular system, regard must be given to the liklihood of mechanical damage, the presence of vibration and the effects of corrosive or solvent agencies and internal condensation. Switches and other ancillary equipment must be of flameproof construction.

Efficient electrical continuity between the lighting fittings and conduit or cable sheathing must be maintained throughout the whole system for earthing purposes. Furthermore, where heavy gauge conduit is employed, the length of a screwed joint (which constitutes the flame path) must be not less than ¼ in. for installations where Groups I, II(a) or II(b) conditions exist, or one inch for other conditions.

A considerable length of conduit attachments represents a large volume internally, and if this was filled with an inflammable gas and ignited a very great force might be generated, particularly as a result of the "pressure piling" induced by the natural conduit formation. It is therefore normal practice to isolate sections of the conduit runs by means of a barrier-type terminal box. Such "stopper-boxes" should also be inserted at points where the conduit passes from a danger to a safe area.

When armoured cables are used, provision must be made, by means of suitable glands, for the effective sealing of the cable at terminal points.

Once installed, a flameproof lighting system must be adequately maintained in good and proper order, and for this purpose the maintenance should be the responsibility of persons who have received instruction in the special technique involved.

Regular mechanical inspections and electrical tests should be instituted and remedial measure arranged where required. No attempt should be made, however, to replace a broken glass except by the complete assembly as obtained from the

manufacturer of the fitting. It is not feasible to quote other than a few examples under this general heading since there are other publications[12] which give guidance on the matter.

(6) Statutory Regulations Affecting the Installation of Flameproof Lighting Equipment

(6.1) Coal Mines[13]

The conditions under which electric lighting may be used in a "safety lamp" mine are clearly defined in the 1947 Regulations. For the lighting of underground roadways, the regulations permit the installation of "approved" equipment (Group I certified) and specify the pressure in the system to be a maximum of 250 volts, with the proviso that in a polyphase system the neutral point should be earthed, and in a system which is not polyphase the mid-voltage point should be earthed.

Electric lighting may be permitted to within 50 yards of the nearest face where there is intake air, or to within 300 yards of the nearest face on return-air roadways; also, under certain conditions, lighting may be permitted to within 10 yards of the face.

As regards the application of mains lighting at the coal-face, the pressure is limited to a maximum of 125 volts and "approved" equipment must be employed. The Regulations require that Section 10 of the Coal Mines (Lighting) General Regulations of 1947 should be supplemented by the Special Regulations relating to "Lighting otherwise than by means of Locked Safety Lamps." These Regulations deal mainly with the requirements of gas testing and inspection of the equipment. Where pneumatic-electric lighting is installed, other regulations apply.

(6.2) Other Industrial Applications[14]

The installation of electrical equipment in the danger areas of factories and the like is controlled by the requirements of several documents depending upon the nature of the hazard. These include the Factories Acts of 1937 and 1948, the Explosives Acts of 1875 and 1923 and certain statutory Rules and Orders made under the Acts, together with the Institution of Electrical Engineers' "Regulations for the Electrical Equipment in Buildings."

The Electricity (Factories Act) Special Regulations, are of primary importance. Although the pertinent regulation (No. 27) is couched in very general terms, simply stating that "All conductors and apparatus exposed to the weather, wet, corrosion, inflammable surroundings or explosive atmosphere, or used in any process or for any special purpose other than for lighting or power, shall be so constructed or protected, and such special precautions shall be taken as may be necessary adequately to prevent danger in view of such exposure or use," it is obvious that the appropriate authorities have wide powers to control the installation of safety lighting equipment in situations where its use is warranted.

Where cellulose solutions are manufactured, used or stored, the Electricity Regulations are supplemented by the Cellulose Regulations which demand that no open light likely to ignite cellulose solutions or inflammable liquids or vapours, shall be allowed within 20 ft. of any inflammable source unless separated from it by a fire-resisting barrier. In addition, it is required that the overall temperature of lighting fittings in those positions where cellulose residues may be deposited on them should not exceed 180 deg F. (82 deg. C.).

Premises where petroleum or explosives are stored are subject to the Regulations and Orders made under the provisions of the Petroleum (Consolidation) Act and the Explosives Acts respectively. Under these regulations, local authorities issue licences for storage, etc., which normally include certain restrictions governing the artificial lighting permitted. With regard to the installation of lighting equipment in factories

and magazines for explosives, the Home Office have issued an explanatory memorandum on the subject; similarly, the Institute of Petroleum have published an electrical code of safety practice in the petroleum industry.

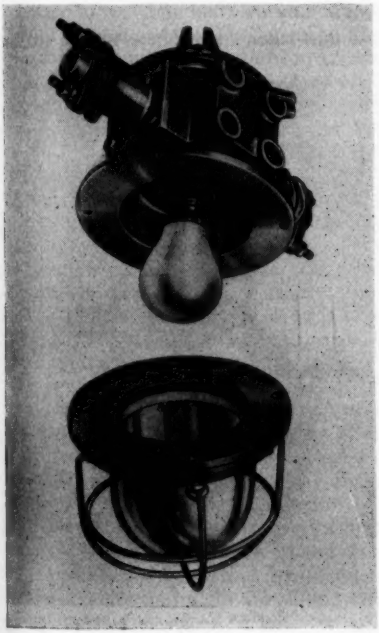
(7) The Application of Flameproof Lighting Equipment

(7.1) General

In situations where pure gas is the hazard, or gas resulting from the evaporation of volatile inflammable liquids, flameproof lighting fittings which have been tested and certified for the particular Group are the obvious choice. There may, however, be border-line conditions where the hazard is confined to a limited area; in such instances, the use of non-flameproof equipment may be permitted, provided that the lighting system is sufficiently remote from the danger area.

On the other hand, there are places and conditions where the excluded (Group IV) gases are present in an explosive mixture and here even the use of flameproof equipment is not generally permitted. For such applications only two methods of illumination can be considered—either an external system in which the light is directed through "windows," or an internal system employing pneumatic-electric (air-turbo) units of specially designed "pressurised" fittings where the conduit, fittings and accessories are hermetically sealed and charged with air or carbon dioxide[15].

A clear distinction must be observed when considering the relative dangers of gases, dusts and fibres. The gas or vapour hazard can be met to some extent by providing sufficient air change in an attempt to keep the gas concentration below the ignitable or explosive limit. With hazardous dusts and fibres, however, the greater the amount



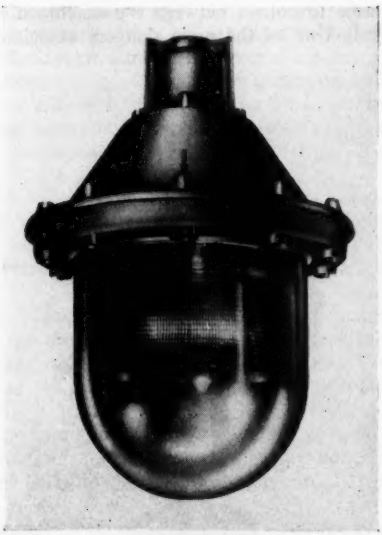


Fig. 7 (left). Typical 60 w. flameproof well-glass fitting to B.S. 889:1947 with mining type glands (Group I).

Fig. 8 (right). 300 w. flameproof lantern with internal refractor (Groups II and III).

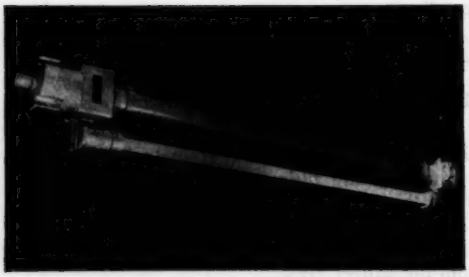


Fig. 9(a). Example of an 80 w. 5 ft. flameproof fluorescent fitting.

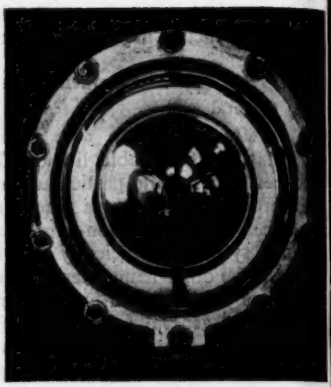


Fig. 9(b). 40 w. circular flameproof fluorescent fitting.

of air (and thus oxygen) supplied, the more complete the combustion is likely to be. If it is not feasible to combat the dust menace at the source, then heavy-duty dust-proof fittings of a type approved by the Home Office will be satisfactory for most installations. For the most explosive dusts, however, flameproof gear may be called for, and an accepted method of guarding against the effects of such dust is to use fittings of flameproof construction and to grease the flanges on assembly so that the dust is not able to collect between the machined surfaces.

One of the main dangers associated with a dust-laden atmosphere relates to the

Fig. 10. Flameproof floodlight (Groups II and III).

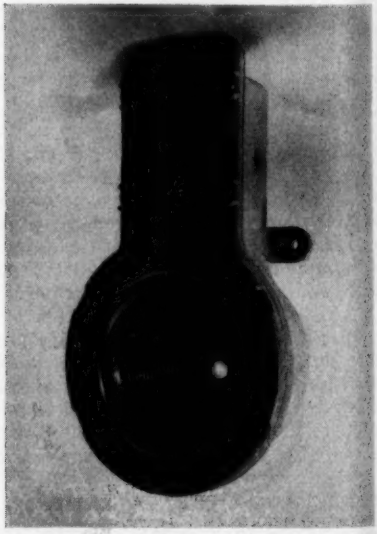


Fig. 11. 150 w. flameproof bulkhead fitting with type 'B' prismatic glass cover (Groups II and III).

increased operating temperature of fittings on which dust is deposited, thereby preventing normal cooling taking place. Regular maintenance provides part of the answer to this problem, but the danger is always present, and particularly so where cellulose solutions may be used[16].

(7.2) Illumination Requirements

The standard of illumination adopted for the lighting of hazardous situations should not normally be less than that required as a minimum by the Factories (Standards of Lighting) General Regulations, 1941[17].

The exceptions include coal mines, where the problems of providing a relatively high standard of illumination underground have been reported elsewhere[18], and those works or parts of factories listed in Part I of the Schedule quoted as an annex to the regulations.

Where practicable, a higher standard of lighting in accordance with the I.E.S. Code for the particular task is to be recommended.

(7.3) Flameproof Lighting Fittings

Notwithstanding the apparent limitations in design imposed by the requirements of flameproof construction, there is available in Britain a fairly wide range of certified equipment to satisfy the demands of those applications where safety lighting is necessary to meet Group I, II or III conditions.

Although the majority of these fittings (which may be certified for one or more Groups) have been designed to employ metal-filament general service lamps, a limited number have been certified for use with low wattage, mercury discharge lamps. In addition, a more recent development has been the introduction of flameproof lighting fittings to accommodate various sizes of fluorescent lamps.

The fittings available for metal-filament lamps range from the standard well-glass pendant and bulkhead patterns to a flameproof floodlight, usually for external mounting, which is suitable for Group II or III applications except where acetone vapours are present; those for use with fluorescent lamps have been designed for the 2-ft. 20-watt to 5-ft. 80-watt sizes, except one which has been developed to accommodate a circular lamp[19]. Special fittings have been developed for particular industries—for example, coal mining.

Apart from the floodlight referred to which can accommodate a 1,000-watt G.L.S. lamp, the normal range of flameproof fittings of the pendant type (with or without reflectors), are designed for lamps up to and including the 300-watt rating, although larger sizes are not precluded except by economic considerations allied to the specified temperature-rise requirements.

Portable handlamps are in a somewhat different category. Whilst there are a number of types available which have passed the flameproof test, only two which are used with a special screened cable have been granted a full certificate. The reason for this is that the normal flexible cable connecting the handlamp to the point of supply may be a potential source of danger in itself[20].

In coal mines there is some demand for flameproof fittings having "plug-in" features to facilitate maintenance and the extension of underground roadway lighting systems, but the added flexibility provided by such an arrangement may not be so important in permanent installations.

During the post-war period the development of flameproof lighting fittings has generally been along conventional lines[21] since their basic design is dictated to a large extent by functional requirements; however, one major trend in construction relates to the increased use of die-cast assemblies—an important contribution when considering the weight factor.

A representative selection of flameproof fittings of the types referred to are illustrated in Figs. 7-14.

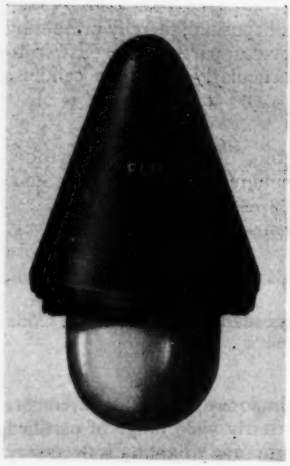
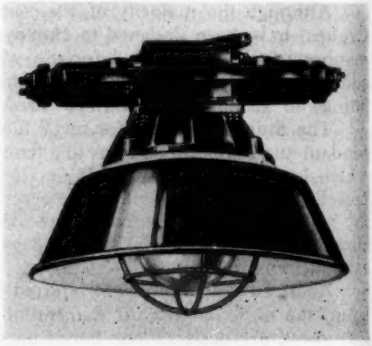


Fig. 12 (left). 150/200 w. flameproof pendant, streamlined pattern (Groups II and III).

Fig. 13 (below left). 100 w. flameproof well-glass fitting with dispersive reflector and industrial type connection box. Main body of aluminium alloy.

Fig. 14. 100 w. flameproof well-glass fitting with dispersive reflector, wire guard and mining type cable glands. Main body of cast iron.



(7·4) Some Applications of Flameproof Lighting Equipment

The situations which necessitate the provision of safety electrical equipment due to the explosion hazard where inflammable gases or vapours may be present as a result of the manufacture, use, handling or storage of inflammable substances, are fairly well defined, by inference, in Section (2.1).

These are many and varied, and include all or some parts of chemical works, gas works[22], coal mines [23], oil refineries[24], paint works, coke oven plants[25], paint spraying establishments, explosives plants[26], etc. The particular hazards are well known, and the installation of the appropriate flameproof lighting equipment is accepted as a matter of course.

A hazard also exists in hospital operating theatres and anaesthetic rooms where an ether-air mixture may be present in the vicinity of the anaesthetic machine. Here the main danger arises from the possibility of electrical sparking and electrostatic charges[27], or hot surfaces which are heated above the igniting temperature. Ceiling mounted lighting fittings, however, are usually sufficiently remote from the possible explosive concentration as not to require special enclosures.

Finally, the application and design of lighting systems for use in areas requiring

flameproof treatment is, in theory, no different from those which employ non-flameproof industrial lighting fittings. In practice, however, there may be some limitations, owing to the fact that the range of certified equipment does not entirely duplicate the very wide variety of standard types of industrial lighting fittings. On occasions the ideal may have to take second place to the practical, but nevertheless each installation should be treated on its own merits in accordance with good modern lighting practice.

(8) Conclusions

The emphasis of this paper has been directed more to the construction and testing of flameproof equipment than to its application in order to record the principles of "flameproof" design as applied to lighting fittings. Provided that the hazards are known and appreciated, the application of such equipment then generally follows the technique of normal industrial lighting practice, except in coal mines where there are special problems. When doubt exists concerning either the hazard or the type of equipment to be used, the Factory Department or Mines Inspectorate should be consulted.

Experience suggests that the appropriate specification dealing with flameproof lighting fittings is, in some respects, now in need of revision and expansion to meet the developments which have taken place during recent years, and it is hoped that this will receive early consideration.

Many of the flameproof lighting fittings for use with incandescent lamps are of the standard well-glass type, in which there is no provision for light control or for limiting the intrinsic brightness of the source. Whilst some are made to incorporate reflectors providing a particular distribution, others are largely inadequate when considering the lighting result. There would, therefore, seem to be some need for extending the present range of lighting fittings of flameproof construction.

Progress in the past few years has been considerable in this important field of lighting practice, and much has been accomplished. The room for further advance, however, is great, and continues to challenge the initiative and resources of the various research and testing organisations.

Acknowledgments

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Discussion

MR. F. H. MANN (H.M. Senior Electrical Inspector of Factories): If I had been asked to take part in the discussion on a paper of this kind 15, or even 10, years ago, I should have expected it to be mainly concerned with telling us how to get a noticeable number of lumens out of flameproof equipment, because that at one time was one of the major problems associated with flameproof lighting. After seeing the excellent illustrations, however, it will be agreed that a sufficient advance has been made to

render it unnecessary for the author to apologise for the deficiencies of flameproof lighting which once were so apparent, and we are now able to fulfil the modest requirements of the lighting regulations with comparative ease.

This paper reviews not only the subject of lighting but the whole question of flameproofness in a very comprehensive way, and one which must have involved a great deal of research. You may like to have some notes on a few points concerned with the more basic aspects of research. Before the practical testing which the author has described is undertaken, a great deal of basic research is carried out on special and standardised test equipment. I must not tread on the toes of the testing authorities or of those concerned with research, because this is their concern rather than ours, but it may be of interest to note that the basic research for the determination of gaps is carried out in an eight-litre sphere, the sphere being selected because it gives the greatest pressure rise. The gaps of this sphere are adjustable and the tests are started with a gap which will ensure an ignition on every test. About 20 tests are made on every gap setting, the gap being reduced by 0.001 in. for each group of tests until no ignitions are obtained. The number of ignitions in each group of 20 tests is then plotted against the gap setting, and this gives a curve which shows the probability of ignition related to the gap width.

At one time it seemed that gap width plotted against the number of ignitions was a linear function, but extended tests (and they amount to over 5,000) at the extremities of the curve, where the gap is respectively small and large, showed that it resembled the integral of the normal distribution curve—the well-known type of curve which you consult to see how many times you can cross a given road without being run over, or to know how long a metal filament lamp may be expected to last. The S-shaped integral of the distribution curve indicates the relation of percentage ignitions to gap width. There is a little asymmetry in fitting the theoretical distribution curve to that obtained by test and we take account of this by extrapolating the integral curve to a point where there is one chance in 1,000 that the probability of one ignition in 1,000,000 is not an under-estimate. In addition to that we apply a factor of safety, and thus think that we are in a position to say that the margin of safety is reasonably secure.

This may give an idea of how this basic research is carried out. It is, of course, only a small part of it, but you may find the statistical assessment of interest, following the author's very practical approach to the subject.

Turning to the paper, in Section 1 the author referred to the pressure being eased by the escape of gases through the gap. Probably it is only a question of the way in which the point has been expressed, but in fact there is no necessity for the pressure to be relieved at all. Flameproof apparatus is built strongly enough to resist the pressure without any release, and the transient pressure cannot be relieved by any release of that kind which, in any event, could hardly be relied on since we are enjoined by B.S. 229 to pull the flanges up as tight as we can so that, if they are machined accurately enough, we may get an air-tight enclosure.

In Section 1.1 the author says that "Any flame . . . will ignite an inflammable gas or vapour," but he goes on to say that "it is possible that a flame which will ignite one may not ignite another." There seems to be a little contradiction here, although it is, of course, true that a flame will ignite any gas. No doubt he will deal with that in replying to the discussion.

At the end of Section 1.1, he says: "In general it should be emphasised that whilst there is no essential difference between the behaviour of various gases and vapours in explosive mixture with air relative to the different means of ignition quoted, there are, nevertheless, wide variations in the reaction between different gases and vapours when ignited by any one method." I am not altogether clear what is meant by this.

In Section 3.2 the author discusses the use of the ¼-in. flange and refers to

BS 229. I do not think that it is giving away any secret to say that BS 229 is under revision, and it is probable that the use of the ½-in. flange will be extended to a greater number of sub-groups subject, of course, to the approval of the testing authority who may not accept the ½-in. flange for very large enclosures where the amount of distortion might very well make it unsafe. The question also arises in connection with conduit; ½-in. would be acceptable for small conduit, but it can well be imagined that with large conduits, for instance 2-in., ½-in. screwing would not be a very good mechanical job.

In dealing with maintenance, the importance of which the author very properly emphasises, it should be pointed out that there is a Code of Practice for the installation and maintenance of flameproof apparatus which deals at some length with the question of maintenance. In his reference to portable apparatus the author mentions air-turbo lamps, with the implication that they could be used for the Group IV gases. Neither of the lamps at present on the market is certified for the "excluded" gases, but we have accepted the use of one of them administratively for hydrogen and acetylene, where we can rely on the standard of maintenance being sufficient to give a reasonable degree of safety.

There is a very profitable field for research where the excluded gases are concerned. Although we have no flameproof apparatus certified at the moment, I can see no reason why apparatus of small volume, such as lighting fittings, should not be developed for the purpose, since the technique now available in the form of screw and spigot methods of construction, as distinct from flanges, may make it possible to secure the necessary small clearances and even, perhaps, the use of flexible gaskets incorporated with the flanges or spigot mountings in such a way that something approaching a gas-tight construction is secured. Research is going forward on this and I hope that we shall have results before long, because one of the greatest needs of industry, with the increasing use of acetylene, hydrogen, carbon-disulphide, and so on, is to have some means of lighting buildings other than by pressuring or external illumination such as the author describes.

The paper refers to dusts, which present another difficulty so far as factories are concerned. There are two major types of industrial dust: carbonaceous dust, which requires a fair supply of air for its ignition and combustion, and explosive dust proper, usually a nitrate, which supplies its own oxygen. Flameproof apparatus has often been suggested as a means of dealing with dusty atmospheres and, because we have no knowledge of the behaviour of flameproof apparatus in relation to dust, we usually suggest that its ingress should be precluded by greasing the flanges. With explosive dusts we are faced with a different problem, because in these the oxygen is in intimate contact with the dust itself and can very well set up thermal conduction, no air being necessary to promote the combustion, and there is thus a chance of combustion extending through the flanges. For that reason flameproof apparatus is not recommended and what we ask for is the best possible means of dust exclusion regardless of the fact that there is no relevant British Standard. The problem of an effective dust seal is another of the many awaiting solution and it is certainly an important one.

The author has reviewed a wide field of the subject of flameproofness and, since about 70 per cent. of the flameproof apparatus installed in this country is installed in industrial establishments it will, I think, be agreed that his review has been very well worth while.

MR. H. S. ALLPRESS: After Mr. Mann's contribution, and the contribution of the author himself in presenting the paper, there seems to be very little that one can add. I would suggest, however, that the author has not quite done himself justice in the title which might well be extended in order to help research workers who are

making bibliographical investigations. The paper covers very much more than simply the design and application of flameproof equipment.

In the Summary he again limits himself to a discussion of flameproof equipment in hazardous atmospheres, particularly in the second paragraph numbered (ii), which to some extent conflicts with Section 7.1 of the paper. I should like to see in this section some recommendation to the factory management to take all possible precautions to remove the medium which constitutes the hazard, a recommendation which should always be mentioned in any paper on flameproof lighting; the spirit of the Act is not that flameproof fittings are primarily intended for continuous application under hazardous conditions, if the gases or vapours cannot be removed by ventilation. The author himself mentions pressurised systems, air turbo units and intrinsically safe lighting, which can frequently be used for more serious purposes than might appear at first sight. In addition, there is the technique of using forced-ventilated fittings in which fresh air is fed by a pipe-line, and that is worthy of mention.

Mention is made later in the paper, with special reference to dustproofing, of greasing the flanges, and reference might also be made to the use of painting or other sealing *after* complete assembly of the fitting. I am very pleased to see that Mr. Strachan draws attention to the danger which arises with intrinsically safe fittings when the glass bulb is broken, because that is sometimes overlooked. It must not be forgotten that that hazard also occurs with flameproof fittings and is not a hazard particularly associated with intrinsically safe fittings.

In Section 1.1 the author draws attention to the danger of using aluminium paint. I have always understood that strictly this refers only to paint applied to fittings which had at some time been rusty and had been treated by being raised to a red heat, so converting the rust to a higher oxide which then, with the aluminium paint, forms a miniature thermite bomb. A new fitting with aluminium paint is not in itself hazardous and I believe is used in industry. I should like this point cleared up.

Mr. Mann referred to the use of flameproof fittings in dusty atmospheres, and here again some further remarks would be of value. There is always some confusion about whether to use flameproofed equipment or not. In some instances the use of flameproof fittings may increase the hazard in dusty atmospheres, and some reference to this—in what is going to be a standard paper of reference—would be of assistance.

In Section 7.4 Mr. Strachan refers to the explosion hazards in hospitals where anaesthetics are used. I should like to refer to the fact that, as these premises do not appear to be covered by other Statutory Regulations, certain local authorities have drawn up their own codes of practice which may call for safety precautions entirely different from those enforceable for similar hazards in industry. Typical of these precautions is the use of mercury switches in place of flameproof switches. This state of affairs is surely most undesirable from many points of view and the author's authoritative comments might go far towards removing such anomalies.

MR. F. WIDNALL: I feel that the author should have given more emphasis to the fact that the lighting efficiency of a fitting is largely controlled by the flameproof requirements. While it is true that, as Mr. Mann has said, with certain lighting fittings just as good a performance can be obtained, with some of the smaller ones the flameproof requirements are very much the ruling factor.

Mention is made in the paper of the researches of Sir Humphrey Davy on the original miners' lamp. I believe it is true that George Stephenson developed a similar safety lamp in parallel with, if not before, Sir Humphrey Davy. It would seem, therefore, that a man with local knowledge occasionally succeeds in putting his finger on the spot and producing the right result without a full scientific or classical research investigation. I do not suggest that that is necessarily true to-day, nor do I deprecate

the research which has been done and which is being done at the present time, but it is as well to remember that occasionally somebody goes straight to the point and by-passes the preliminary work.

On the question of further developments, it seems to me that one of the weak features of the present specifications relates to the cements approved for flameproof fittings. When they were first developed, a good deal of work was done on these cements and resulted in a relatively satisfactory solution to the problem, but it is only a *relatively* satisfactory solution and I think that there is scope for a good deal more development. I am afraid that it will be rather a long business; it will have been obvious from the author's film and from what Mr. Mann has said that any investigation of flameproof equipment is bound to be a long and tedious process but that does not lessen the need for the work to be undertaken.

Then there is the question of changes of specification and the vexed question of temperatures of fittings. Designers must remember that despite the fact that we are often annoyed by the limitations of the flameproof requirements, which always seem to prevent one taking the extra step which looks so attractive, the flameproof mark is an international hall-mark and is taken as a guarantee throughout the world. That is a very great asset so far as flameproof equipment is concerned and, although there are many things which I should like to see changed—at least when I am doing any designing—regarding the requirements for flameproof equipment, my sympathies to some extent lie with the people concerned with the research work, testing and so on who are, shall we say, not very anxious to move too quickly. I should like to hear the author's views on that, because as a user I think that he must at times also have felt that he would like to go quicker—but I wonder whether he really would?

MR. J. COWAN (Principal Electrical Inspector of Mines): This is a practical paper, and a great deal of work has gone into it. The author may say that he knows very little about flameproof enclosure, but to my mind he deals adequately with the subject. He mentions that in the earlier days flameproof enclosure depended chiefly for safety on venting devices, and he says that these took the form of spring-loaded bolts and devices of that type. The general result was a cheap form of construction, but we soon found that the vents became choked, stopped up and rusty and as a result fractures of the enclosures sometimes occurred. That was rectified by requiring a stronger enclosure and laying down certain conditions regarding the minimum strength of the enclosure.

Mr. Mann mentions that the path to obtaining a flameproof certificate is a long one, and he reminds us that 70 per cent. of all the apparatus which is covered by flameproof certificates is used in factories. I have suggested to him in a friendly manner that we in the Ministry of Fuel and Power might be able to help him to deal with applications and certifications for such purposes. However, he has not taken the bait, and apparently prefers to rely on the Ministry for testing for all kinds of gases.

Before we can deal with the first application from manufacturers, and often in less than a fortnight, there is an application for another supplementary, and after three weeks or so there may be three or four supplementaries to the original application. That results in a long delay, because almost every application for a supplementary certificate is different from its predecessor. A little forethought by the manufacturer in the early stages of his application would save a great deal of time. If he would ask in the first application for all the variations to be covered it would also save time.

In my Annual Report, which is now in the hands of the printers, I make the point that we suffer a good deal because in the applications which we receive from manufacturers—even from long-established and experienced manufacturers—it is some-

times impossible to read the drawing and frequently all the facts are not given. In other words, it would appear that some manufacturers do not even read B.S. 229 or Testing Memorandum No. 4. All these things contribute to delay.

The author mentions the use of flameproof apparatus where dust is the hazard, and I must support Mr. Mann there. So far as we are concerned, we make no attempt to cover a flameproof apparatus for use when there are explosive dusts; we do not know sufficient about the problem, and the certificate does not cover use in locations where there may be explosive dusts. We only test apparatus in the prescribed gas. I would also counsel caution about putting grease on the flanges. A great deal depends on how much grease is put on the flanges as a safeguard as the gap may be excessively increased.

We know that in some structures under test the bolts may be strained, and there may be a movement between the two halves of the flanges during an explosion test so that a gap is created at the moment of test.

I like the point which the author makes with regard to the care which must be exercised when dealing with intrinsically safe circuits. The bulb may form part of the circuit, and the bulb may be easily damaged. Mr. Allpress said that that applies equally to flameproof enclosures, but there is a difference. In some factory certificates dealing with intrinsic safety the bulb is not in a flameproof enclosure, so that the envelope is structurally weak when any damage takes place. There is a great difference between a bulb in a flameproof enclosure and one which is not, and that is a point worth noting. Where there is any danger of igniting gas, lamp bulbs should preferably be in a flameproof enclosure.

Mention has been made of aluminium alloys. This point has come very much to the fore recently, because we have found that if a casing made from an alloy with a certain magnesium content is dropped from a certain height, say 6 ft., on to a rusty steel plate, the spark which is caused may ignite certain gases. The result is that it has been suggested to the Coal Board and to those concerned with factories that they should consider carefully whether aluminium alloys should be used in flameproof equipment. At the moment we are accepting alloys in which the magnesium content does not exceed 1 per cent.—or possibly a little more in certain circumstances —but the whole question of aluminium alloys has to be carefully considered.

I am trying to persuade manufacturers that aluminium alloys in lighting fittings, pushbuttons and other apparatus on the coal face should ultimately be replaced by some other material, if at all possible.

Mr. Allpress mentioned aluminium paint. For the information of members I would say that we are not now accepting any flameproof apparatus in which aluminium paint is part of the design or structure.

There has been some talk regarding the temperature rise of fittings. The most recent information which we have had from the E.R.A. leads us to think that we should be wise to keep to our present standards.

Mr. Widnall sympathises with us when we are testing apparatus, and he appreciates, from a wide knowledge of the subject, that it takes a long time to make changes in testing procedure. I agree with him that the "FLP" mark is known throughout the world as the leading flameproof certificate. I had an opportunity of attending meetings of the International Electrotechnical Commission on flameproof enclosure, and it was obvious from the start that all our friends on the Continent paid respect, verbally or otherwise, to the Buxton certificate, which is held in very high regard. We may advance slowly, but I think we go surely, and that is the most important point. If we can go surely but more quickly, so much the better, but we cannot always do that.

Mr. Mann referred to the ½-in. flange on certain apparatus. It is not generally possible to use the ½-in. flange on a structure of a size larger than about 1 foot cube.

In larger structures under welding conditions the ½-in. flange may be lost; I have seen a structure about 2 x 1 x 1½ ft. in which the original ½-in. flange had become distorted under the stresses set up during welding. As Mr. Mann mentioned, the same holds true for conduit, where ½-in. on a 2½-in. conduit would be rather ridiculous; this width should probably be confined to 1-in. conduit.

The author refers to the use of a stopper-box. Generally where a stopper-box is used it should be fitted permanently to the piece of apparatus which is being covered by the certificate and not some distance away from the structure. A stopper-box is always required where the diameter of the conduit exceeds 1 in.

Mr. Mann mentioned the problem of hydrogen. They also have this problem on the Continent. The Germans, I understand, test apparatus in hydrogen, but it is not effective with any piece of apparatus other than those of very small size.

MR. H. G. JENKINS: The chief subject for discussion, as the author has mentioned, is fittings, and therefore he may perhaps be excused for not referring to the intrinsic safety of the source itself, or its degree of intrinsic safety; but surely that enters into the design of the fitting? He will probably admit that a tubular fluorescent lamp is intrinsically much safer than a tungsten filament lamp; it would appear, therefore, that a less rigorous design of fitting for such a lamp could be used.

Before the war we were called in to help the Mines Research Board with sources which were intrinsically safe, and amongst the various sources which were tried was an ordinary cold-cathode tube operated by a 300 + 300-volt transformer. It happened to be a fluorescent tube using the only highly efficient phosphor available at that time, a green-coloured willemite, but that is by the way. My point is that that was tested at Buxton and was found to be intrinsically safe in acetylene-air mixtures. I should like to ask why these sources, which have such a good factor of safety, have not been put to greater use for lighting places subject to explosive atmospheres, particularly since it would appear that complicated flameproof fittings would not then be required.

MR. S. ANDERSON: I should like to know what is regarded as a suitable safety factor on these flameproof enclosures. So far as I can see, the procedure is to test with a given maximum gap under the most unfavourable and dangerous conditions which can be produced, and if the equipment passes the test, it is satisfactory; but surely it is only sound engineering practice to have a safety factor over and above what is just adequate to avoid ignition of the surrounding gas mixture? For a straight hydraulic or pneumatic pressure test on a well-glass the problem of determining the safety factor is simple, but how is it decided when an adequate safety factor exists in a gap clearance, or the width of a flange, or something of that sort?

I was glad to hear the author's views on the desirability of either making the starter in a flameproof fluorescent fitting easily accessible for renewal, or preferably standardising on the starterless type of circuit for fluorescent flameproof fittings. It seems to me that one may spend a good deal of money and exercise much ingenuity in making the starter easily accessible, when it would be simpler and cheaper to dispense with it by using an instant-start type of circuit.

I have for a long time been a supporter of the idea of lighting buildings housing dangerous material from the outside, and I was interested to note that the author mentioned that method, particularly where Group IV gases are present. Obviously the method is not applicable to a mine, but for the many quite small buildings in which there are dangerous mixtures in factories, I feel that it is a method of lighting which is often far less complex, and probably far less costly, than the installation of certified flameproof fittings in the interior to give a similar illumination. As the author has

said, it is not always easy, using flameproof equipment, to provide the high levels of illumination required for some processes.

I was interested in a remark made in the discussion about the danger of an incendive spark caused by dropping an aluminium alloy fitting on an iron structure. It occurs to me that one of the most common implements used in any sort of mining operation is a pick, and if I remember rightly, when a pick strikes a piece of flint or rock it is likely to produce a spark. How is that hazard regarded by the authorities?

MR. S. HUBBOLD: I have one comment to make on the subject of temperature rise. Mr. Cowan has mentioned the sure but slow progress we make, but I feel that in restricting the temperature rise to 50 deg. C., we are making progress backwards. Let me quote an example: In the same room we can have a flameproof heater with a surface temperature of about 400 deg. C. rise and a lighting fitting which is limited to 50 deg. C. rise.

Before the introduction of B.S.889 the only surface temperature limit was for equipment used in cellulose industries and many fittings had cast on them either "Not to be used in Cellulose Industries" or "Not to be used with a lamp above a certain wattage when used in Cellulose Atmospheres." It worked very well and I do not know of a single instance where the wrong type of fitting was used.

We must remember that British manufacturers have an export market to consider and this will suffer if we have to make our fittings large and expensive. I hope that when the B.S.I. Committee get down to settling the revisions to B.S.889 they will consider this and concern themselves primarily with the safety aspect of the apparatus.

I do not know of any other country that limits the temperature rise for all groups to 50 deg. C. Indeed, the Germans go as high as 400 deg. C. for certain groups. They have different temperatures for different groups and in general adopt a sensible attitude.

At the time of the introduction of B.S.889 new lamps, such as the 2½ kw. Compact Source lamp were being introduced and under the existing regulations people could not be prevented from putting a 2½ kw. lamp in a 60-watt fitting so long as it would go in. Some temperature limitation was therefore desirable, but I feel that in limiting every fitting to a 50 deg. C. rise we have gone too far.

MR. F. N. BEAUMONT (written contribution): The paper is an excellent summary of to-day's position, and whilst the author emphasises that it has been directed more to the design of flameproof equipment than to application, it is the various aspects connected with application that greatly exercise the minds of engineers and any experiences that can be reported are of great practical value to all industries. My remarks, however, are concerned with this problem in the oil industry.

The Institute of Petroleum in their Electrical Code give guidance for the oil industry regarding the classification of refinery areas into "Dangerous" and "Safe" and give recommendations for the type of electrical equipment which should be installed therein, with particular reference to flameproof equipment. This code also recommends minimum distances from "dangerous" areas which may be assumed "safe." It is probable that this "minimum" recommendation accounts for what appears at first sight as widely differing standards adopted by oil companies; some managements do accept the minimum distance for a "safe" area, but others prefer to adopt a high factor of safety—as the result possibly of experience and peculiar local conditions—by extending the limits of the "dangerous" area. Looking at this interpretation in its bearing on this paper, means either the minimum or maximum application of flameproof equipment; the classification of an area must rest with the operating management whose decisions are related to safety to life and security of production.

As the author points out, considerable testing and research relative to flameproof

apparatus is being carried out continually and much valuable data is produced. In this connection, however, the user is considerably concerned when he finds that certified apparatus which has been installed for some time appears to fall short of requirements for current certification by virtue of the interpretation of the results of this research. It is, of course, agreed that one must necessarily take action when subsequent investigations prove a previous theory to be incorrect or unsound, but nevertheless, the user should be in a position to assume that apparatus which carries a certificate continues to be regarded as certified unless the certifying flameproof certificate is withdrawn. Without such a procedure the user may find himself in a position of false security.

Design of apparatus to meet flameproof requirements must, of course, rest with the manufacturer, and it is most heartening to find that liaison with the Ministry of Fuel and Power is such that designs can be offered for which certification can be confidently expected. As certification necessarily takes quite a considerable time it is obvious that occasions will arise when users must design installations and utilise apparatus which does not at the moment carry the Buxton mark, but is in course of manufacture on the assumption that it will eventually carry a certificate.

Methods of installation of flameproof equipment are of considerable importance, and in this connection, cabling probably causes greater concern than the fittings themselves. Conduit has given considerable trouble due to collection of moisture and the effects of corrosion. There are, however, I consider very great possibilities in the protective properties of P.V.C. as an external sheathing to cables to protect them against the effects of corrosion. Such cables are being extensively used in new refineries now under construction. It must be noted that fittings must be designed to be capable of connection to varying systems of cabling.

The use of flameproof lighting in external locations subject to weather conditions gives rise to severe problems due to the ingress of moisture; the solution is undoubtedly a flameproof, weatherproof fitting. The use of grease between the flanges sometimes assists but it is not a real solution, and the incorporation of a gasket to seal the fitting against ingress of moisture is probably the only satisfactory answer. I consider that the design itself should cover weatherproof requirements and not rely on staff to apply the right grease in the right place at the right time.

MR. D. A. STRACHAN (in reply): I would like to thank all those who have taken part in the discussion, particularly Mr. Mann and Mr. Cowan for their authoritative contributions.

Mr. Mann referred to some of the more basic aspects of research relating to flameproof testing, which I am sure will be of considerable interest since he summarises the work leading to the determination of the permissible gap widths.

In reply to Mr. Mann's query regarding my statements in Section 1.1, I would like to amplify what I have written there by saying that, in general terms, each inflammable gas and/or vapour has a time lag on ignition and its own particular igniting temperature. For example, a flame of extremely short duration may ignite hydrogen but not necessarily another gas, say, methane; hence my reference to the fact that there are variations in the reaction between different gases and vapours when they are ignited by any one means.

I am grateful to Mr. Mann for bringing to our notice the fact that B.S.229 is constantly under review and for referring to the B.S. Code of Practice, which relates to the installation and maintenance of flameproof equipment.

Mr. Mann rightly differentiates between carbonaceous and explosive dusts, and I agree that for the latter, one should recommend the use of heavy-duty dust-proof fittings which would be of a type approved by the Home Office for such applications.

Mr. Allpress makes the point that, where possible, an effort should be made to

remove, or at least to restrict, the hazard by means of forced ventilation. Where the hazard results from a gas or vapour, I agree that this may be practicable since a sufficient air change may result in the gas concentration being kept below the ignitable or explosive limit. However, with carbonaceous dusts the greater the amount of air (and thus oxygen) supplied, the more complete the combustion is likely to be should an ignition occur. Nevertheless, I agree that the hazard should be tackled at the source if possible.

Mr. Allpress also refers to the use of flameproof fittings where an explosive dust constitutes the hazard. Regarding the general question, I think Mr. Mann has already supplied the answer—flameproof fittings having their flanges suitably greased or painted after assembly may be acceptable where carbonaceous dusts are encountered, but heavy-duty dust-proof fittings are necessary where explosive dusts are present. Where flameproof fittings may be employed, I would suggest that those certified for use under Group III conditions should be selected since they have the smallest maximum permissible gap, but there is no specific ruling. On the score of cost, however, dust-proof fittings would appear to be the better proposition.

The point raised by Mr. Allpress regarding the application of aluminium paint was adequately answered by Mr. Cowan in his contribution to the discussion in which he stated that the use of an aluminium paint is not acceptable for flameproof lighting fittings.

Mr. Allpress mentions the question of mains lighting at the coalface, and I know that he is well aware of the problems associated with its successful application. Conditions are so different and the problem so complex that the standards of illumination achieved underground should not be compared with those accepted for surface installations. Whilst it is the constant aim of the mining industry to improve underground lighting generally, it is hardly correct to say that this can be achieved with such a small capital outlay as Mr. Allpress suggests.

Mr. Widnall spoke as a fittings' designer, and quite rightly said that the design of any fitting must be influenced, to a large extent, by the flameproof requirements. He also referred to the question of cements. Those for glass to metal bonding are well established, but consequent upon the possible introduction of an acrylic plastic as part of the flameproof enclosure for some types of fittings, I agree that there is scope for further research on suitable cements for this application.

In reply to Mr. Widnall's last point, I would say that whilst we may wish to progress as quickly as possible, we must be certain that we are progressing in the right direction. I therefore favour "making haste slowly" when it comes to the question of fundamental research and testing.

There is little for me to comment upon in Mr. Cowan's authoritative contribution—in fact I think he has been good enough to answer more questions than he has asked.

Among other things, Mr. Cowan refers to one difficulty associated with the certification of flameproof equipment, namely, the request for supplementary certificates which is made soon after a particular piece of equipment has been certified. This must necessarily lead to some delay and I agree with Mr. Cowan that manufacturers would be well advised, where possible, to include the required variations with their initial application.

I am grateful to Mr. Cowan for his comments on the ½-in. flange in which he suggests that this breadth of flange, when applied to conduit and its accessories, should be confined to the 1-in. size.

In reply to Mr. Jenkins, it is true to say that the tubular fluorescent lamp is regarded as being inherently more safe than a metal filament lamp. Tests (on 2-ft. lamps) have shown that the discharge arc itself will not ignite a mixture of methane and air, but in the hot-cathode lamp the filaments are a potential source of ignition

should the lamp be broken under starting conditions; however, due to rapid cooling, this is not so should the lamp be broken whilst it is in operation. As a matter of interest, I can also report that since the date of the original experiments, some further tests have been conducted on a limited number of cold-cathode lamps operating in conjunction with an auto-transformer and no ignitions resulted when breaking these lamps in an 8 per cent. methane mixture. This does not prove that such lamps are intrinsically safe in themselves as further research is called for, but it does perhaps point a trend.

Mr. Jenkins asks whether lamps of this type could be employed in non-flameproof fittings under hazardous conditions, but this would not be permitted since one must have a flameproof enclosure at the terminal points where the cable enters the fitting; furthermore, there is the possibility of arcing at the lampholder contacts and it therefore follows that the fitting as a whole must be certified as flameproof.

Mr. Anderson raises a question with regard to the "safety factor" of flameproof enclosures. I think Mr. Mann has already given the answer relative to the risk of ignition, during his explanation of the work associated with the determination of the permissible width of gaps in flameproof enclosures. Regarding the "safety factor" as applicable to the mechanical construction of an enclosure, this is covered by Clause 23 of B.S. 229, which requires that the flameproof enclosure must withstand an internal pressure of not less than one and a half times the maximum pressure developed while undergoing its test flameproofness, or of 50 lb. per sq. in. above atmospheric pressure, whichever is the greater. In addition, a gun-cotton test may also be applied at the discretion of the testing authority.

Mr. Anderson's final point is one which I understand to be under investigation and it is therefore premature for a firm answer to be given. However, I believe that the particular risk referred to depends not only upon the heat of the spark produced, but also on the nature of the substances involved.

Mr. Hubbold has remarked upon the temperature test requirements demanded by B.S.889 and in his capacity as a designer, I have some sympathy with the problem he poses. Nevertheless, I doubt whether he would find much support among the majority of industrial users of flameproof lighting fittings for his proposal to increase the temperature rise already specified, but no doubt this matter will receive due consideration when the Standard comes under review.

Finally, I am indebted to Mr. Beaumont for his written contribution, which specifically refers to the application of flameproof lighting equipment in the oil industry. There is little to comment upon except to confirm that a user is correct in regarding any item of equipment which carries a flameproof certificate as "certified" until such time as the manufacturer has the particular certificate withdrawn by the Ministry of Fuel and Power.

Mr. Beaumont rightly refers to the difficulties associated with the application of standard flameproof lighting equipment in external locations and it is true to say that this problem can only be met by the introduction of a range of flameproof fittings which are of weatherproof construction.

Annual General Meeting

The annual general meeting of the Illuminating Engineering Society was held at the Cambridge Hall, Lord Street, Southport, at 4 p.m. on Friday, May 21, 1954. The president, Mr. W. R. Stevens, was in the chair. The secretary having read the notice convening the meeting and the statement of the auditors for the past year, it was agreed that the minutes of the last meeting be taken as read and were approved.

Report and Accounts for 1953

The president then presented the report of the Council for 1953. (See *Transactions*, Vol. XIX, No. 3, 1954.) He pointed out that for the first time the total membership had decreased during the year; it was obviously undesirable that this should be so and the Council was therefore looking into the reasons for it and was reviewing the activities of the Society as a whole. He referred to the successful one-day meeting organised by the centres in the Midlands and suggested that it was an idea which might be taken up by other centres. He recalled that during the year a new group of the Society had been formed in the Transvaal, the first group to be formed outside the United Kingdom; from reports received it appeared that the new group had made a good start and was enrolling new members to the Society. At this point the president expressed the appreciation of the Council and of the Society as a whole of the work done by the honorary secretaries of centres and groups on whose efforts and enthusiasm the success of the Society in the provinces so much depends.

Referring to the list published in the report of Society representatives on committees of other organisations the president said that the amount of work undertaken on behalf of the Society and the industry in this way was not fully appreciated and he expressed thanks on behalf of the Council to those who gave so much time and effort on this aspect of the Society's work.

On finance he said that the balance at the end of the year had been greater than had been expected; this was due to careful management and partly to the fact that some papers intended for publication in the Transactions could not be published during the year. Whilst speaking of the Society's publications he also expressed appreciation to the Illuminating Engineering Publishing Co. Ltd. for the improvements which had been made to *Light & Lighting* as from the beginning of the current year.

The adoption of the report and accounts was proposed by Mr. C. C. Smith (Liverpool Centre), who said that in his opinion the two outstanding features of the year under review were the visit of Dr. Ward Harrison and the Trotter-Paterson Memorial Lecture given by Dr. E. D. Adrian. He said it was a matter of great disappointment to note from the report the poor attendance of members of Council at Council meetings. He said he felt that if members are prepared to take office they should also be prepared to undertake the duties that go with the office including attendance at meetings. As far as the general health of the Society was concerned he thought that the attendance at the summer meeting at Southport (during which the annual general meeting took place) was a sufficient indication that the Society was doing good work and that its efforts were appreciated. He concluded by proposing the adoption of the report and accounts and proposing a vote of thanks to the president, officers and members of Council for their conduct of the Society's affairs during the past year.

The proposal was seconded by Mr. H. Carpenter (North Lancashire Group), who said that the centres and groups were also concerned with the present drop in membership and he was glad that the Council was taking some action in this matter. He suggested that steps should be taken to secure more sustaining members amongst firms, and particularly amongst local government authorities, who have

much to gain by membership of the Society.

The report and accounts were carried unanimously and the president returned thanks on behalf of the officers and members of Council.

Election of Officers and Members of Council

The president reported that there had been no other nominations for officers and members of Council for the Session 1954-55 and the Council's nominees, as follows, were therefore declared elected:—

President: Mr. E. C. Lennox.

Vice-Presidents: Mr. H. G. Campbell, Mr. C. S. Caunt, Dr. W. E. Harper, Mr. A. G. Penny, Dr. J. W. Strange.

Hon. Treasurer: Mr. E. B. Sawyer.

Hon. Secretary: Mr. H. C. Weston.

Hon. Editor of the Transactions: Mr. C. R. Bicknell.

Members of Council: Mr. D. S. Allom, Mr. A. W. Gostt, Mr. A. G. Higgins, Mr. G. E. V. Lambert, Mr. A. H. Olson, Mr. C. C. Smith, Mr. J. S. Smyth, Mr. H. E. G. Watts.

The president expressed the thanks of the Society to retiring officers and members of Council, in particular to Dr. W. E. Harper, who had been responsible for editing the Transactions for the past three years.

This concluded the formal business of the meeting.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members:—

SUSTAINING MEMBERS:—

S. A. Philips (PTY), Ltd. ..... *Representative*: H. K. Koerting
Upper Railway Road, Cor., Herb Street, New Doornfontein, P.O. Box 7703, JOHANNESBURG.

Simplex Electric Co. (S.A.) (PTY), Ltd. ..... *Representative*: J. A. Morrison
P.O. Box 751 Springs, Hassett Road, Nuffield, Springs, SOUTH AFRICA.

CORPORATE MEMBERS:—

Bowl, M. D. .....40, Brancaster Road, Seven Kings, ESSEX.
Braiden, T. .....39, Oreson Street, BELFAST.
Bromley-Gans, J. M. ...36, Ennis Road, Parkview, JOHANNESBURG.
Carmichael, G. .....Church View, Wistow, Nr. Selby, YORKS.
Drake, W. B. M. .....32, St. George's Square, LONDON, S.W.1.
Dring, A. W. .....65, Middle Street North, Driffield, YORKS.
French, W. A. A. .....159, Evington Road, LEICESTER.
Mast-Ingle, H. R. .....56, Second Street, Linden, JOHANNESBURG.
Verbeek, L. H. .....c.o. Bibliotheekcentrale, N. V. Philips' Gloeilampenfabrieken, Eindhoven, HOLLAND.

OVERSEAS MEMBERS:—

Broom, M. E. .....865, Washington Avenue, Memphis 5, TENNESSEE, U.S.A.

STUDENT MEMBERS:—

Adams, A. R. .....61, Thirteenth St. Parkhurst, JOHANNESBURG.
Michie, H. .....234, Regent Street East, Observatory Extension, JOHANNESBURG.

TRANSFER FROM STUDENT TO CORPORATE MEMBERSHIP:—

Doo, S. A. .....3, Chalkhill Road, Wembley Park, MIDDX.

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